
Contents

Introduction	ix
Chapter 1. PHM and Predictive Maintenance	1
1.1. Anticipative maintenance and prognostics	1
1.1.1. New challenges and evolution of the maintenance function	1
1.1.2. Towards an anticipation of failure mechanisms	3
1.2. Prognostics and estimation of the remaining useful life (RUL)	5
1.2.1. What is it? Definition and measures of prognostics	5
1.2.2. How? Prognostic approaches	6
1.3. From data to decisions: the PHM process	9
1.3.1. Detection, diagnostics and prognostics	9
1.3.2. CBM Architecture and PHM process	10
1.4. Scope of the book	12
Chapter 2. Acquisition: From System to Data	15
2.1. Motivation and content	15
2.2. Critical components and physical parameters	16
2.2.1. Choice of critical components – general approach	16
2.2.2. Dependability analysis of the system and related tools	17
2.2.3. Physical parameters to be observed	19
2.3. Data acquisition and storage	20
2.3.1. Choice of sensors	22
2.3.2. Data acquisition	23
2.3.3. Preprocessing and data storage	24
2.4. Case study: toward the PHM of bearings	25

2.4.1. From the “train” system to the critical component “bearing”	25
2.4.2. Experimental platform Pronostia	26
2.4.3. Examples of obtained signals	30
2.5. Partial synthesis	30
Chapter 3. Processing: From Data to Health Indicators	33
3.1. Motivation and content	33
3.2. Feature extraction	35
3.2.1. Mapping approaches	35
3.2.2. Temporal and frequency features	36
3.2.3. Time–frequency features	38
3.3. Feature reduction/selection	48
3.3.1. Reduction of the feature space	48
3.3.2. Feature selection	54
3.4. Construction of health indicators	62
3.4.1. An approach based on the Hilbert-Huang transform	62
3.4.2. Approach description and illustrative elements	62
3.5. Partial synthesis	63
Chapter 4. Health Assessment, Prognostics and Remaining Useful Life – Part A	67
4.1. Motivation and content	67
4.2. Features prediction by means of connectionist networks	69
4.2.1. Long-term connectionist predictive systems	69
4.2.2. Prediction by means of “fast” neural networks	77
4.2.3. Applications in PHM problems and discussion	84
4.3. Classification of states and RUL estimation	88
4.3.1. Health state assessment without <i>a priori</i> information about the data	88
4.3.2. Toward increased performances: S-MEFC algorithm	93
4.3.3. Dynamic thresholding procedure	95
4.4. Application and discussion	97
4.4.1. Tests data and protocol	97
4.4.2. Illustration of the dynamic thresholding procedure	101
4.4.3. Performances of the approach	104
4.5. Partial synthesis	105

Chapter 5. Health Assessment, Prognostics, and Remaining Useful Life – Part B	109
5.1. Motivation and object	109
5.2. Modeling and estimation of the health state	111
5.2.1. Fundamentals: the Hidden Markov Models (HMM)	111
5.2.2. Extension: mixture of Gaussians HMMs	117
5.2.3. State estimation by means of Dynamic Bayesian Networks	118
5.3. Behavior prediction and RUL estimation	124
5.3.1. Approach: Prognostics by means of DBNs	124
5.3.2. Learning of state sequences	124
5.3.3. Health state detection and RUL estimation	126
5.4. Application and discussion	129
5.4.1. Data and protocol of the tests	129
5.4.2. Health state identification	131
5.4.3. RUL estimation	133
5.5. Partial synthesis	135
Conclusion and Open Issues	137
Bibliography	143
Index	163